Draft Work Plan
Marcellus Shale Risk Assessment

Background

Risk is a measure of the probability and consequence of uncertain future events. It can be thought of as the chance of an undesirable outcome and it is often described by this basic risk equation:

Risk = Probability x Consequence

Risks can be assessed qualitatively or quantitatively. Quantitative risk assessment is preferred when data and other resources are sufficient to support it. Qualitative risk assessment is a valid and valued alternative means of examining the evidence base to make estimates of risk under conditions of uncertainty in order to support decision making.

There are insufficient data to perform a quantitative assessment of the risks of gas production in the Marcellus Shale; therefore, a qualitative risk assessment is proposed. This assessment will use the available evidence to deconstruct the basic risk equation into its component parts, each which can then be qualitatively assessed on the basis of the best available evidence. The components will then be aggregated to develop qualitative ratings of the overall probability and the overall consequence of a specific risk, which can be combined to yield an overall risk potential. Conceptually, this deconstruction could be expressed in this equation

$$Risk_a = (P_{a1} \times P_{a2} \times \ldots P_{an}) \times (C_{a1} + C_{a2} + \ldots + C_{am})$$

where $Risk_a$ is the risk of outcome "a", $(P_{a1} \times P_{a2} \times \ldots P_{an})$ represents the sequence of *n* events that is necessary for risk "a" to occur and $(C_{a1} + C_{a2} + \ldots + C_{am})$ represents the separate kinds of consequences that may result if that sequence of events did occur. The sequence of events and the resultant consequences could vary from one risk to another.

This method is well established in the risk literature and in practice. It is, for example, the methodology used by the United States Department of Agriculture's Animal Plant Health Inspection Service to evaluate the risk associated with importing plant and plant products into the US. This same methodology is used by the International Plant Protection Convention of the United Nations to assess plant risks. This same methodology is being used at the present time by the U.S. Army Corps of Engineers to assess the risk of establishment of aquatic nuisance species as part of the Congressionally mandated Great Lakes and Mississippi River Interbasin Study (GLMRIS, sometimes better know as the Asian carp study).

The Scope of the Risk Assessment

The Departments will consider routine risks associated with drilling into the Marcellus Shale and stimulating the well using high volume hydraulic fracturing as well as risks associated with accidents. A team of subject matter experts from MDE and DNR will be assembled to evaluate the risks. If needed, expertise from outside

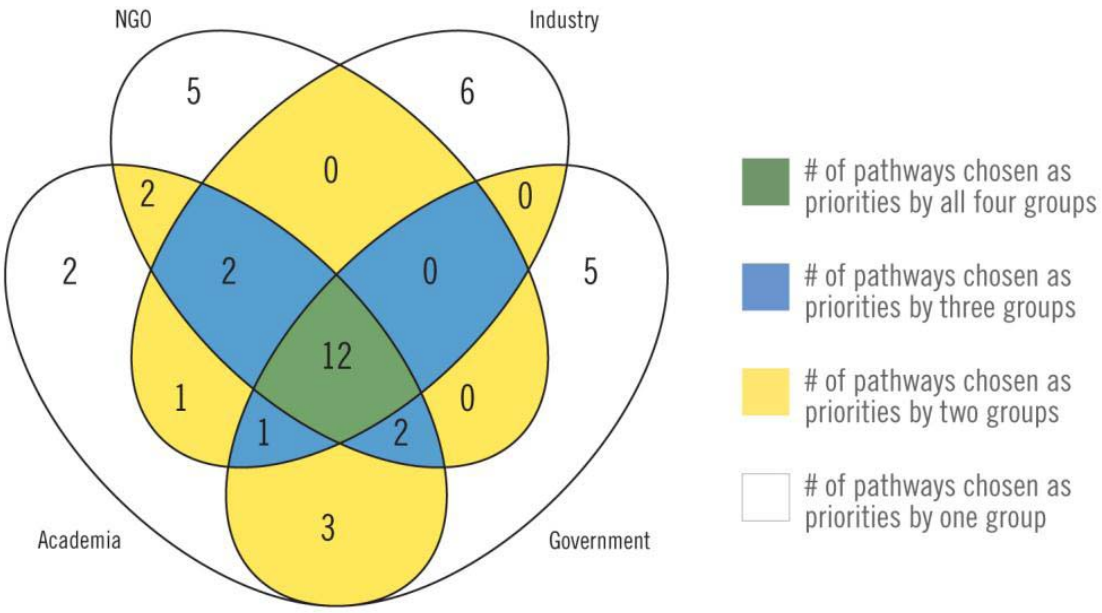
the Departments will be consulted. All steps of the risk assessment, including the basis for the classifications, will be documented and included in a report.

Choosing the Risks to Evaluate

Routine Risks

Our initial focus will be on the risks identified as among the top 20 priority risks by one or more expert groups[1] in the Resources for the Future (RFF) survey of experts, the results of which were published as *Pathways to Dialogue: What the Experts Say about the Environmental Risks of Shale Gas Development.* The RFF survey presented a matrix listing widespread drilling activities and the adverse impact (RFF calls these "burdens") that could plausibly follow from the activity. Participants were asked to prioritize the risks. As shown in this figure from the RFF report, there was substantial overlap in the choices of the different expert groups, with twelve appearing in the top 20 of each of the four groups. Forty-one risks were identified this way and are listed in Table 4 and Table B6 of the RfF report, and appear in the Appendix to this work plan.

Figure 3. Degree of Agreement among the Expert Groups' 20 Priority Risk Pathways



The members of the Advisory Commission will be asked if there are additional risks that should be added beyond the 41 or if some risks should be eliminated. The Executive Order can be a guide to identifying the risks.

Risks from Accidents

The RFF survey also gave participants the opportunity to choose from 14 potential accidents and provide their qualitative assessment of the probability that they could

[1] The groups were: NGOs, Industry, Academia, and Government.

occur and the severity of the consequences. We propose to start with the top 7 of the 14 accidents in Table 16 of the RFF report, which are listed in the Appendix to this work plan.[2] The members of the Advisory Commission will be asked if there are additional risks arising from accidents that should be added.

Evaluation of routine risks

The risks will be screened by the MDE/DNR team to eliminate those activities, if any, that would not occur in Maryland because of existing laws or regulations. The remaining risks will be evaluated as follows:

1. Identify the sequence of events that could lead to the consequence.
2. Collect available evidence on the probability that each step in the pathway could occur.
3. Assign a qualitative value to the probability that each step will occur: low, medium or high. Where evidence is lacking, use best professional judgment.
4. Assign a rating to the consequence: minor, moderate or serious.
5. Identify best practices or other steps that could reduce the risk.
6. Prepare a summary for each risk that rates the seriousness of the consequence and explains how the probability of occurrence was evaluated.

Evaluation of risks of accidents

1. Is there any data on the frequency of these accidents in the unconventional gas drilling sector?
2. If not, is there any data on the frequency of these accidents in general?
3. If not, qualitatively rate the probability as low, medium or high taking into account the level of confidence. Where evidence is lacking, use best professional judgment.
4. Assign a rating to the consequence: minor, moderate or serious.
5. Identify best practices or other steps that could reduce the risk.
6. Prepare a summary for each risk that rates the seriousness of the impact, demonstrates the effect that deploying best practices recommendations have on overall risk and explains how the probability of occurrence was evaluated.

Schedule (tentative; also some steps may continue or be repeated as new information becomes available)

Dates	Task
October through December 2013	Identify risks and begin collecting data
January 2014	Assemble team
February through April 2014	Evaluate risks

[2] The other 7 were chosen by fewer than 30% of all the experts who participated in the RFF survey

May 2014	Prepare draft report
June 2014	Prepare final repost

Appendix

Initial List of Risks (Adapted from Table B6 of the RFF Report)

	Impact to	From	Activity
1	Surface water	Flowback and produced water constituents	Stored in on-site pits or ponds
2	Surface water	Flowback and produced water	Treatment, release by a municipal wastewater treatment plant
3	Groundwater	Flowback and produced water	Stored in on-site pits or ponds
4	Surface water	Stormwater flows	Clearing of land for roads, well pads, pipelines, evaporation ponds, and other infrastructure
5	Surface water	Freshwater withdrawals	Use of surface water and groundwater during fracking
6	Groundwater	Freshwater withdrawals	Use of surface water and groundwater during fracking
7	Surface water	Fracturing fluids	On-site pit or pond storage
8	Air quality	Methane	Venting of methane during fracking
9	Surface water	Flowback and produced water	Treatment, release by a industrial wastewater treatment plant
10	Air quality	Methane	Venting of methane during drilling
11	Habitat	Habitat fragmentation	Clearing of land for roads, well pads, pipelines, evaporation ponds, and other infrastructure
12	Surface water	Fracturing fluids	Storage of fracturing fluids at drill site
13	Groundwater	Methane	Casing and cement
14	Surface water	Flowback and produced water constituents	Flowback of reservoir fluids
15	Surface water	Drilling fluids and cuttings	Disposal of drilling fluids, drill solids, and cuttings
16	Surface water	Flowback and produced water constituents	Application of wastewater fro road deicing, dust suppression

	Impact to	From	Activity
17	Surface water	Flowback and produced water constituents	Well production
18	Groundwater	Drilling fluids and cuttings	Disposal of drilling fluids, drill solids and cuttings
19	Groundwater	Flowback and produced water constituents	Flowback of reservoir fluids
20	Surface water	Fracturing fluids	Treatment, release by municipal wastewater treatment plants
21	Surface water	Drilling fluids and cuttings	Storage of drilling fluids at surface
22	Surface water	Drilling fluids and cuttings	Drilling equipment operation at surface
23	Community	Seismic vibrations	Deep underground injection
24	Groundwater	Freshwater withdrawals	Use of surface water and groundwater during drilling
25	Community	Industrial landscape	Clearing of land for roads, well pads, pipelines, evaporation ponds, and other infrastructure
26	Community	Road congestion	On-road vehicle activity during site development
27	Community	Road congestion	On-road vehicle activity during drilling
28	Community	Road congestion	Transport off-site
29	Community	Noise pollution	Drilling equipment operation at surface
30	Groundwater	Intrusion of saline water	Casing and cementing
31	Community	Road congestion	On-road and off-road vehicle activity during fracking
32	Surface water	Freshwater withdrawals	Use of surface water and groundwater during drilling
33	Groundwater	Flowback and produced water constituents	Well production
34	Air quality	VOCs	On-site pit or pond storage

	Impact to	From	Activity
35	Air quality	Conventional air pollutants and CO_2	Compressor operation
36	Air quality	VOCs	Condensate tank, dehydration unit operation
37	Groundwater	Fracturing fluids	On-site pit or pond storage
38	Groundwater	Intrusion of saline water	Drilling of vertical and lateral wellbore
39	Groundwater	Fracturing fluids	Storage of fracturing fluids at drill site
40	Groundwater	Flowback and produced water constituents	Deep underground injection
41	Groundwater	Drilling fluids and cuttings	Drilling equipment operation at surface

Initial List of Accidents (Adapted from Table 16 of the RFF Report)

1. Cement failure
2. Casing failure
3. Impoundment failure
4. Surface blowout
5. Storage tank spills
6. Truck accidents
7. Pipeline ruptures